(12) UK Patent Application (19) GB (11) 2 028 528 A

(21) Application No 7919930
(22) Date of filing 7 Jun 1979
(23) Claims filed 7 Jun 1979
(30) Priority data
(31) 935187
(32) 21 Aug 1978
(33) United States of America (US)
(43) Application published 5 Mar 1980
(51) INT CL³ G02F 1/01
(52) Domestic classification G2F 23E 25C 25F 25P2 SX G5C A342 A353 HG
(56) Documents cited
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(58) Field of search G2F G5C
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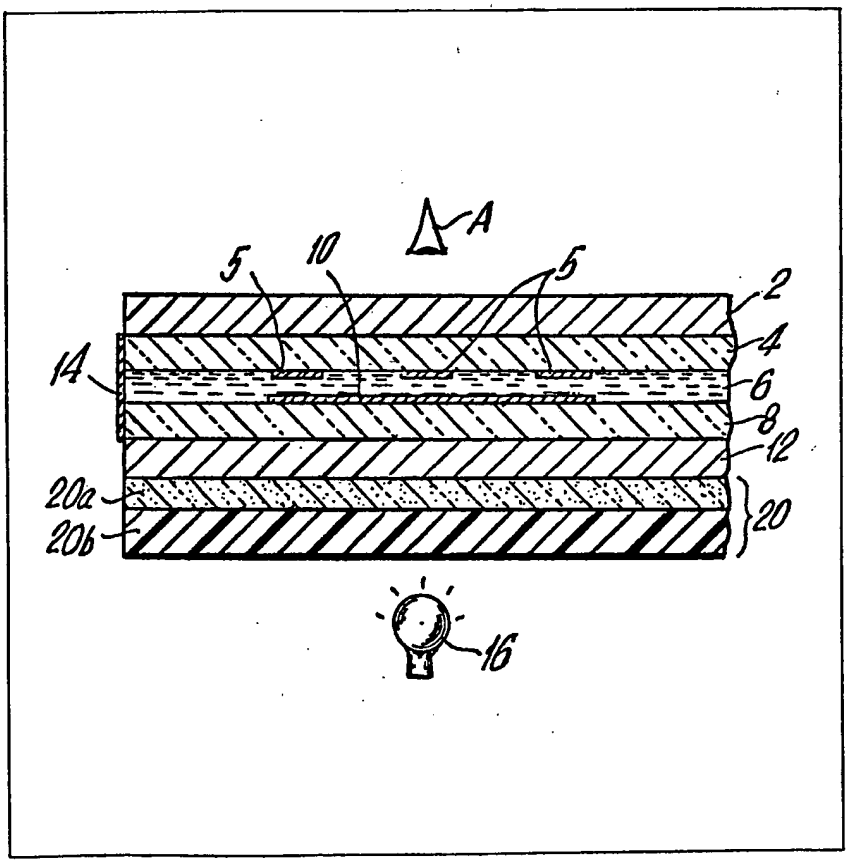
(54) Illuminated electro-optic display device with improved transflector

(57) An illuminated liquid crystal display device operative in the reflective and transmissive modes has a transflector 20 comprising a translucent plate-like member including a layer of white translucent material 20*b* having a certain minimum effective thickness (0.040 inches) in the primary direction of light propagation in the device such that ambient light incident upon the white layer during daylight viewing is subjected to enhanced diffusion, fringing and brightening to provide a brighter appearing background and darker-appearing display characters to the daytime viewer for improved contrast and also to provide an apparent increase in the "brush-stroke" width of the display characters to the same viewer. Layer 20*b* is of white styrofoam, chalk, paint, paper or cloth and is bonded to a layer 20*a* of polystyrene, polypropylene or styrofoam. The transflector is also applicable to electrochromic, electrolytic or electrophoretic display devices.



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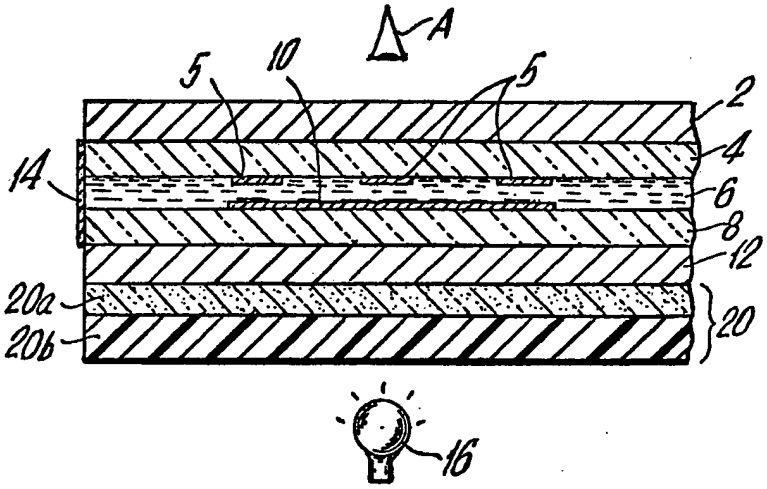
A
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10
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2
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14
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20a
20b
20
16

SPECIFICATION

Illuminated electro-optic display device with improved transflector

The invention relates to illuminated electro-optic display devices and, more particularly, to such display devices which are operative in the reflective and transmissive modes and include a so-called transflector for this purpose.

Various types of electro-optic display devices have been employed for electronic wristwatches, clocks, and other apparatus. One type of display is the field effect, twisted nematic liquid crystal display device, the operation and construction of which is well known and described, for example, in U.S. Patent No. 3,731,968. It is also well known that displays can operate both in the reflective and transmissive modes; i.e. using either reflected ambient light for daytime viewing or backlighting with one or more actuatable light sources behind the display for nighttime viewing.

Also known are means for illuminating clock dials using a light source with means to first disperse the specular light rays to the desired location and then to diffuse, i.e. scatter, the light in a particular area.

A particular type of known liquid crystal display includes a liquid crystal cell having image-forming electrodes, upper and lower polarisers on opposite sides of the cell and a so-called transflector behind the lower polariser. A light source is typically positioned behind or at the side of the transflector for directing light therein. The transflector functions essentially as a one-way mirror so that the display can operate in the reflective mode in ambient light and in the transmissive mode at night with the aid of backlighting by the light source. In daylight, ambient light enters the display and passes through the liquid crystal cell, where it may be optically altered, and then is reflected from the transflector back toward the observer. At night, the transflector receives light from the light source and transmits it upwardly toward the observer by light scattering, diffusion, and reflection within the transflector. As a result of the light diffusion effected by the transflector, the display characters are more or less uniformly illuminated. A typical transflector may comprise silvered glass or glass with a grey filter. However, other materials which are transluscent to light have also been widely used. Exemplary of these are styrofoam of white, grey or silver hue, polystyrene, and polpropylene in thin layers or sheets.

Although satisfactory back lighting or liquid crystal displays has been achieved with the aid of a transflector, it has not been obtained without some sacrifice in the daylight viewability of the display. More specifically, the quality of the daylight image has been adversely affected by the transflector in that a reduction in the contrast between the image and background, especially a dark image on a light background has been observed. Of course, any reduction in the contrast ratio of a liquid crystal display adversely affects not only the aesthetic appeal to the observer but also its utility. To this end, a concentrated effort has been made to improve the quality of daylight viewability of back-lighted liquid crystal displays employing transflectors.

Accordingly, it is an object of the present invention to provide an improved transflector for use with illuminated electro-optic display devices, especially those of the liquid crystal type operative in the reflective and transmissive modes, to overcome the aforementioned disadvantages of the prior art.

The invention provides accordingly an electro-optic device including an electro-optic display cell operative either in a reflective or a transmissive mode and having a plurality of selectively actutable electrode segments to form display characters, a light source for night illumination and a transflector member made of translucent material and disposed behind the display cell to diffuse and reflect incident ambient light for daytime viewing and to diffuse, reflect and transmit light received from the light source for night viewing, wherein the transluscent transflector member adversely affects daytime viewability when the display characters are dark against a light background by reducing contrast therebetween, and said transflector member includes at least a layer portion made of white transluscent material and having at least a minimum effective thickness in the principal direction of light propagation in the device such that ambient light incident upon said white transflector layer is subjected to sufficiently enhanced diffusion, fringing and brightening to provide a brighter-appearing background and darker-appearing display characters to the daytime viewer and also to provide an apparent increase in the "brush-stroke" width of the display characters to the same viewer, thereby improving daytime contrast and overall viewability, and said transflector member also enhances the readability of the display characters during night viewing as a result of enhanced diffusion, fringing and brightening of light received from said light source.

In a typical embodiment of the invention relating to liquid crystal displays, the improved transflector is positioned behind the lower polariser of the display sandwich and is in the form of a transluscent plate-like member including as an essential and important feature thereof a layer portion of white transluscent material having at least a minimum effective thickness in the principal direction of light propagation in the device such that ambient light incident upon the white transluscent layer during daytime operation is subjected to sufficiently enhanced diffusion, fringing and brightening by said layer that the display characters appear darker and the background appears brighter to the daytime observer and also that the "brush-stroke" width of the display characters is apparently increased to the same observer. The net effect of the improved transflector is to provide a liquid crystal display

having better daytime contrast between the display characters and background and better overall daytime viewability than liquid crystal displays employing prior art transflectors. Furthermore, as a result of enhanced diffusion, fringing and reflection of light received by the transflector from the light source of the device, the night viewability of the display is also considerably improved.

In a preferred embodiment of the invention, the white transluscent layer of the improved transflector comprises a white styrofoam sheet of the required minimum thickness bonded in a sandwich or lamellar structure to one or more layers of styrofoam or other transluscent materials.

The present invention will be more fully understood from the following description of a preferred embodiment shown in the accompanying drawing which is a cross-sectional view of an illuminated liquid crystal display employing an improved transflector.

Referring first to the drawing, the details of a typical liquid crystal display device will be discussed although they are well known in the art. The device comprises a top polariser sheet 2, a transparent substrate 4 having transparent electrodes 5, a thin layer 6 of twisted nematic liquid crystal material of positive dielectric anisotropy, some examples being given in U.S. Patent No. 3,731,986, a second transparent substrate 8 with transparent electrode 10 thereon and a bottom polariser 12 having its axis crossed relative to top polariser 2. Of course, those skilled in the art will recognise that the thicknesses of the display components are greatly exaggerated in the drawing for purposes of clarity. Especially exaggerated is the thickness of the liquid crystal layer 6 and electrodes 5, 10 which in actual practice is only about one mil thickness. The liquid crystal material is sealed between substrates 4, 8 at the periphery by means such as epoxy resin 14. A light source 16 is positioned behind the display in conventional fashion for night viewing. Of course, the light source may be selected from various types including, but not limited to, an incandescent lamp, light emitting diode, beta-light and the like, and may be arranged in other co-operative positions relative to the display, such as for example adjacent the edge of one or both of the transparent substrates or above the top polariser.

In accordance with the present invention, an improved transflector typically in the form of a plate-like member 20 is positioned behind bottom polariser 12 and in front of light source 16. As shown, the transflector plate may be of sandwich or lamellar construction having layers 20*a* and 20*b* of one or more different transluscent materials. The important feature of the transflector, however, is that at least one of the layers or lamellae, for example 20*b*, be made of white transluscent material and have at least a certain minimum effective thickness in the principal direction of light propagation through the device, i.e. the vertical direction in the drawing, such that ambient light penetrating the white layer during day viewing is subjected to sufficiently enhanced diffusion, fringing and brightening as compared to that effected with prior art transflectors to provide a brighter-appearing background and darker-appearing display characters to the daytime viewer at A and also to apparently increase the "brush-stroke" width of the display characters to the same viewer. Not only is the daytime contrast between the display characters and background improved by the brightening effect on the ambient light as a result of diffusing and reflecting from the white transluscent layer but also the overall quality of the daytime display is improved by the combination of said brightening and the increase in "brush-stroke" width of the display characters resulting from enhanced scattering and fringing of the ambient light reflected from the white transluscent layer. As used herein, "brush-stroke" width is intended to mean the width of any segment of the viewed character.

Of course, the attributes of the display device employing the improved transflector make the device especially useful in horological instruments, in particular, electronic wristwatches,

The minimum effective thickness required for the white transluscent layer 20*b* will depend upon several factors; including the type of translucent material utilized in the different layers of the transflector. White styrofoam sheet or plate has been found to be a preferrred material for the white transluscent layer 20*b*. It has been determined that when transflector layer 20*a* is polystyrene sheet having a thickness of 0.015 inch, a white styrofoam sheet of 0.055 inch thickness is sufficient to impart improved daylight contrast and overall viewability to a twisted nematic liquid crystal display of conventional construction as shown in the drawing. When the transflector layer 20*a* is white styrofoam of 0.040 inch thickness, an additional white styrofoam layer 20*b* of 0.040 inch thickness has proved satisfactory in practising the invention. In general, a white transluscent layer 20*b* at least 0.040 inch in thickness is satisfactory regardless of the particular transluscent layer 20*a* employed. Those skilled in the art will recognise that in the illustrated embodiment, transluscent layer 20*a* may be selected from available transluscent transflector materials including, but not limited to, silvered glass, glass with a conventional grey filter, styrofoam of white, grey or silver hue, polystyrene or polypropylene. Although white transluscent styrofoam is the preferred material for transflector layer 20*b*, other useful materials, such as for example white paint, white chalk; white paper, white cloth, as well as others, will become apparent to those skilled in the art. Typically the transflector sandwich is formed by adhesively bonding the different layers together using conventional adhesives and techniques. Of course, transflector constructions other than the sandwich or lamellar type can also be utilized in the

invention and these will be readily apparent to those skilled in the art. If desired, the transflector sandwich may be joined by adhesive or other means to the bottom polariser 12 to form a one-piece component.

In addition to enhancing the daytime viewability of the liquid crystal display, the improved transflector 20 has been found to also substantially improve night viewability by providing enhanced diffusion, fringing and reflection of the light received from light source 16. The improvement in night viewability is manifested in the ability of the viewer to easily read the display characters in total darkness with the unaided eye.

Although the present invention has been described in detail hereinabove with respect to liquid crystal display devices, it is not so limited. For example, the improved transflector may find use in other illuminated electro-optic display devices such as electrochromic, electrolytic, electrophoretic and other devices. Furthermore, while the invention has been explained with respect to certain specific embodiments, it is understood that other uses are possible and that various modifications and substitutions can be made within the scope of the appended claims.

CLAIMS

1. An electro-optic device including an electro-optic display cell operative either in a reflective or a transmissive mode and having a plurality of selectively actuatable electrode segments to form display characters, a light source for night illumination and a transflector member made of translucent material and disposed behind the display cell to diffuse and reflect incident ambient light for daytime viewing and to diffuse, reflect and transmit light received from the light source for night viewing, wherein the transluscent transflector member adversely affects daytime viewability when the display characters are dark against a light background by reducing contrast therebetween, and said transflector member includes at least a layer portion made of white translucent material and having at least a minimum effective thickness in the principal direction of light propagation in the device such that ambient light incident upon said white transflector layer is subjected to sufficiently enhanced diffusion, fringing and brightening to provide a brighter-appearing background and darker-appearing display characters to the daytime viewer and also to provide an apparent increase in the "brush-stroke" width of the display characters to the same viewer, thereby improving daytime contrast and overall viewability, and said transflector member also enhances the readability of the display characters during night viewing as a result of enhanced diffusion, fringing and brightening of light received from said light source.

2. The electro-optic device of Claim 1, wherein the electro-optic cell is a liquid crystal cell and first and second polarisers are disposed on the top and bottom sides of the cell, the improved transflector member being disposed behind said second polariser.

3. The electro-optic device of Claim 1, wherein the improved transflector member is a sandwich construction of two or more transluscent layers bonded together, at least one of which is said white transluscent layer.

4. The electro-optic device of Claim 3 wherein the white transluscent layer is a sheet of white styrofoam of effective thickness.

5. The electro-optic device of Claim 4, wherein the other transparent layer is selected from the group consisting of polystyrene, polypropylene and styrofoam.

6. The electro-optic device of Claim 1, wherein said layer portion of white translucent material is at least 0.040 inch in thickness.

7. A liquid crystal display device including a liquid crystal cell operative either in a reflective or a transmissive mode and having a plurality of selectively actuatable electrode segments to form display characters, first and second polarisers on the top and bottom sides of the cell, respectively, a light source for night illumination and a transflector member made of transluscent material and disposed behind the second polariser to diffuse and reflect incident ambient light for daytime viewing and to diffuse, reflect and transmit light received from the light source for night viewing, wherein the transflector member adversely affects daytime viewability when the display characters are dark against a light background by reducing contrast therebetween, and said transflector member comprises a plate-like member which includes a layer of white transluscent material having at least a minimum effective thickness in the principal direction of light propagation in the device such that ambient light incident upon said white transflector layer is subjected to sufficently enhanced diffusion, fringing and brightening to provide a brighter-appearing background and darker-appearing display characters to the daytime viewer and also to provide an apparent increase in the "brush-stroke" width of the display characters to the same viewer, thereby improving daytime contrast and overall viewability, and said transflector member also enhances the readability of the display characters during night viewing as a result of enhanced diffusion, fringing and brightening of light received from said light source.

8. The liquid crystal display device of Claim 6, wherein the improved transflector member is a sandwich construction of two or more transluscent layers at least one of which is said white transluscent layer.

9. The liquid crystal display device of Claim 7, wherein the transflector sandwich and bottom polariser are joined together to form a one-piece component.

10. The liquid crystal display device of Claim 8, wherein the white transluscent layer is a sheet of white styrofoam of required thickness and is bonded to a sheet of polystyrene, polypropylene

or styrofoam.

11. The liquid crystal display device of Claim 10, wherein the styrofoam sheet is on the bottom of the sandwich.

12. The liquid crystal display device of Claim 6, wherein the actuatable electrode segments are configured to form horological display characters.

13. An electro-optic display device substantially as hereinbefore described with reference to the accompanying drawing.

Printed for Her Majesty's Stationery Office by the Courier Press, Leamington Spa, 1980. Published by the Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.